Seaweb Network for FRONT Oceanographic Sensors

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http://nopp.uconn.edu/
http://www.onr.navy.mil/sci_tech/ocean/#sensing

LONG-TERM GOAL

The goal is to use acoustic energy, modern electronics, digital communication theory, and specialized networking techniques for wireless data telemetry and remote control of distributed undersea sensors.

OBJECTIVE

This project advances communications technology in support of the scientific objectives of the NOPP Front-Resolving Observational Network with Telemetry (FRONT) effort. We apply undersea acoustic communication (telesonar) and seaweb networking now being developed for ocean surveillance and other Naval missions. These technologies provide data telemetry and command and control capabilities for a set of widely spaced oceanographic sensors at an environmentally complex site on the North American continental shelf.

APPROACH

Spatial sampling of ocean fronts on the inner continental shelf (20-60 m deep) requires undersea sensor distribution over roughly a 20-km by 20-km geographic area. Sparse sensor placement at the FRONT site, as charted in Figure 1, poses a technological challenge for reliable delivery of data to shore and sensor control from shore. Vulnerability of cables to boat anchors and commercial trawling precludes the use of a wired sensor network. Vulnerability of surface buoys to weather, rough seas, and pilfering discourages reliance on radio telemetry from individual sensor nodes to shore or to space satellite.

An undersea acoustic network is a cost-effective alternative enabled by recent and ongoing technology developments for distributed littoral surveillance. Such a distributed network involves multiple sensor nodes, relay nodes, and gateway nodes, as depicted in Figure 2. With ONR sponsorship, SSC San Diego is advancing telesonar digital communications for use in adverse acoustic channels similar to those existing between sensor nodes at the FRONT site. Presently implemented M-ary Frequency Shift Keyed (MFSK) telesonar signaling is inherently channel tolerant, and ongoing developments will yield adaptive modems that probe the channel,

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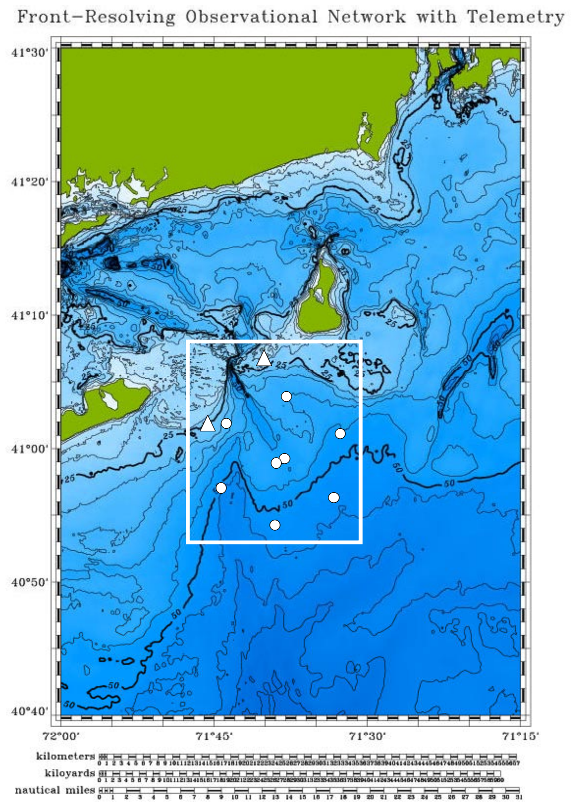

Figure 1. The original concept for FRONT node placement involved eight sensor nodes and two gateway nodes in 20- to 60-m continental shelf water.

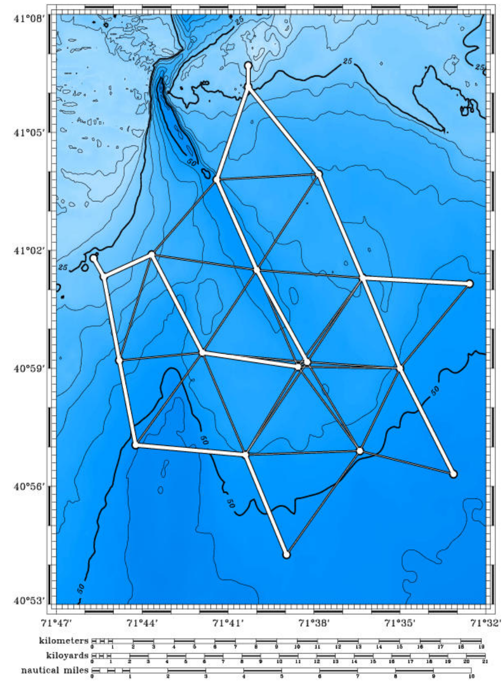

Figure 2. Relay nodes reduce node spacing and improve overall quality of service. Binary-tree routing topologies minimize multi-access channel contention for half-duplex telesonar links. Routes are configurable by ashore network administrator using the seaweb server.

estimate the prevailing propagation characteristics, and then adjust the signaling parameters for optimized energy efficiency and channel capacity.

Telesonar networks support packetized data telemetry from network nodes as well as remote control and interrogation of specific sensor nodes from ship and shore sites, or via the internet. The operational concept is known as "seaweb," and SSC San Diego is committed to executing a series of progressive Seaweb experiments on an annual basis. Seawebs '98 and ’99 proved the viability of delivering asynchronous digital data from various commercial oceanographic sensors via multiple battery-powered telesonar nodes. Seaweb 2000 employed the new ATM885 telesonar modem specifically built for networked applications. Future Seaweb experiments will demonstrate increasingly sophisticated telesonar networks with fixed and mobile nodes. With the objective of self-configuring, scaleable networks for undersea warfare applications, we are performing basic research in acoustic propagation and coordinating the development of signaling theory, modems, directional transducers, gateway concepts, handshake protocols, network designs, and multi-user access strategies.

We are working toward a long-range goal of networking dissimilar, arbitrarily placed, stationary and mobile, undersea nodes using auto-configuration, self-optimization, self-healing, and

environmental adaptation. FRONT is much less demanding because it can be pre-planned and remotely configured. Hence the FRONT application is well matched to the present telesonar state-of-the-art. We are developing telesonar technology to support the Littoral ASW Deployable Autonomous Distributed System (DADS) with topologies, throughput requirements, and battery constraints similar to those of FRONT. Thus, pertinent multi-access interference issues and resource-optimization issues are being addressed. Likewise, RF gateway technologies and a command-center user interface known as the seaweb server have direct application to FRONT.

We carefully position the FRONT sensor nodes, repeater nodes, and gateway nodes to provide maximum flexibility and redundancy in the network. Multiple routes exist between sensor nodes and gateway nodes, permitting the shore-based network administrator to remotely reconfigure the network. Thus, a limited number of node failures can be tolerated and network performance and endurance can be optimized. Likewise, we can assimilate new node additions at any time. Such a network provides near-real-time data from the FRONT observatory while simultaneously providing the Navy an appropriate case study for Seaweb technology development. Telesonar and seaweb technology will advance appreciably during the three-year FRONT project because of hardware and software developments now underway. These technology improvements will be introduced to the FRONT network to incrementally improve quality of service. Meanwhile, the FRONT application lets SSC San Diego relate network performance to a demanding time-variant ocean environment expected to be well-characterized by FRONT oceanographers.

Our FRONT network design optimizes quality of service and energy efficiency for a given stationary deployment in a known environment. We are measuring and analyzing the site for acoustic propagation and preferred node placement, including use of relay nodes for improved communication links, redundancy, and data relay to near-shore gateway nodes. We are working with our NOPP partners to define and compress communication packet content. Data packets of 1 to 4 kbits are anticipated.

In FY00, we have installed Navy telesonar modems to form the FRONT-1 and FRONT-2 networks. Our University of Connecticut (U Conn) partners installed a cellular telephone at a Coast Guard buoy near Montauk Point, NY which served as the only gateway. FRONT-2 used the new ATM885 modems.

In FY01, FRONT-3 will use the Navy's Seaweb 2000 technology in a 4- to 6-month deployment. After the NOPP partners analyze frontal

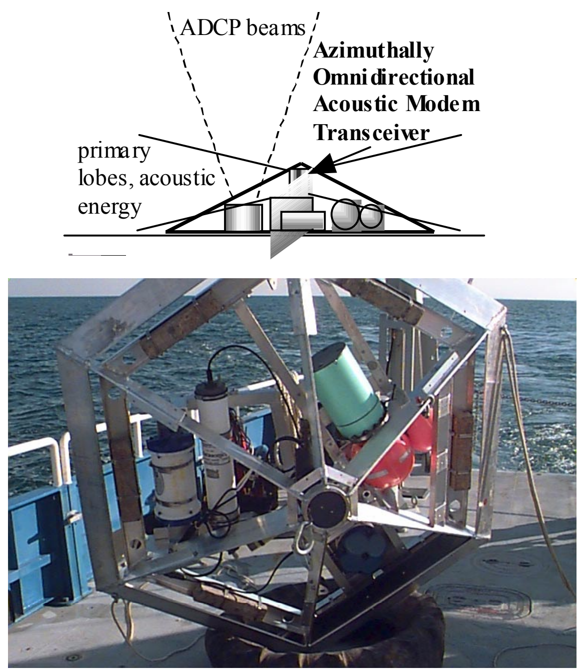

Figure 3. <u>Top</u>: Design and function of bottom-mounted instrument frame. Low-profile pyramidal shape is intended to deflect trawling gear. To enable azimuthally omni-directional acoustic communications, all components other than the acoustic modem transceiver are positioned below the main lobe of the telesonar transducer beampattern. <u>Bottom</u>: Prototype sensor node frame in upright position recovery.

phenomena from FRONT-3, we will redesign the sensor network to permit the sampling of specific features or finer scales, probably by including additional nodes. We will again test the network and FRONT sensors during Seaweb 2001. U Conn will procure twenty telesonar modems from Benthos and will install two gateway nodes for dedicated use during FRONT-4 deployments. SSC San Diego will test this equipment with integrated sensors as Seaweb 2001 assets.

In FY02, the FRONT-4 installation will ensue with modems running Seaweb 2001 firmware, and we will maintain ocean observation for up to ten months.

WORK COMPLETED

This three-year project began in the fourth quarter of FY99. At the end of FY00, we have performed a series of at-sea engineering experiments in association with FRONT partners U Conn and Benthos. These deployments include:

experiment	*dates*	*sensor nodes*	*gateway nodes*	*total nodes*
Seaweb '99	Aug-Sept, 1999	3	2	15
ForeFRONT-1	Oct, 1999	1	1	3
FRONT-1	Dec, 1999	2	1	7
ForeFRONT-2	April, 2000	2	1	8
FRONT-2	June, 2000	2	1	8
Seaweb 2000	Aug-Sept, 2000	4	3	17

The Seaweb experiments are prolonged, intensive engineering activities largely funded by other SSC San Diego telesonar projects, and they serve to substantially advance the modem and network technology on an annual basis. We perform the ForeFRONT experiments at the FRONT site for mitigating risks and learning about the seasonal propagation environment. The FRONT experiments are longer duration deployments with near-real-time oceanographic data collection. Sensor nodes are mostly ADCPs housed in a trawl-resistant frame as in Figure 3. A 4-element line array transducer is mounted in the apex of the frame and provides vertical directionality. Figure 4 shows the USCG buoy at the 25-m isobath instrumented as a telesonar gateway node with a 3-m deep telesonar transducer and a Bell Atlantic cellular modem. Through this gateway, the ForeFRONT and FRONT networks are linked to the internet and are monitored by the SSC San Diego seaweb server.

Figure 4. USCG buoy serves as a FRONT gateway buoy.

RESULTS

Seaweb '99 included fifteen telesonar nodes deployed in the shallow waters of Buzzards Bay. During Seaweb '99, we found issues related to interfacing RDI ADCP sensors with ATM875 telesonar modems. In preparation for ForeFRONT-1, these issues were resolved. During Seaweb '99, we accessed the telesonar network using a network gateway installed on a USCG caisson. Below the caisson a stock telesonar modem provided access to neighbor nodes. We interfaced

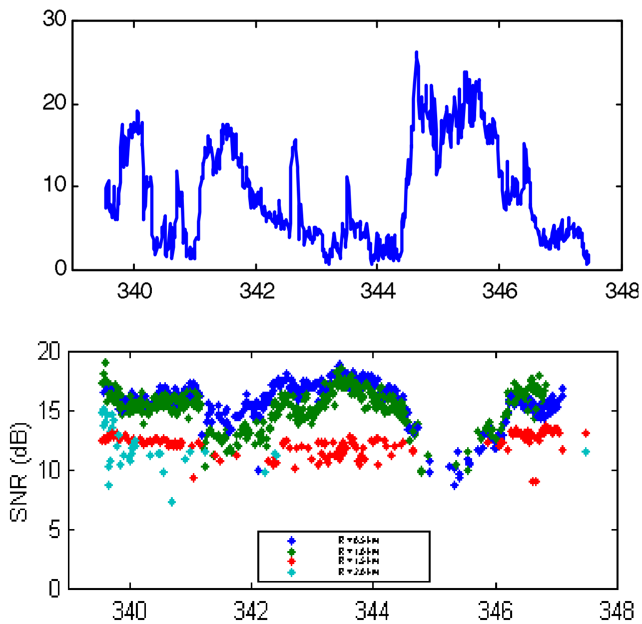

Figure 5. Top: Wind speed (kts) during an 8-day winter deployment. Bottom: Acoustic modem signal-to-noise ratios for transmissions between fixed locations at ranges 0.5, 1.0, 1.5, and 2.0 km. Strong winds significantly impair communications in this upward-refracting environment.

the modem to a Bell Atlantic cellular telephone mounted on the caisson above the waterline. This provided a TCP/IP link to any authorized internet server. In this case, the link was tested at the Seaweb command center manned by project personnel. During Seaweb '99, we implemented a rudimentary command-center user interface using a National Instruments LabView application installed on a laptop PC running Windows NT. We accessed the telesonar network using both the TCP/IP gateway and a point-to-point packet radio link to a second gateway node. Seaweb '99 demonstrated bidirectional communications, with remote-control commands to the seaweb network and data delivery from the seaweb network. During Seaweb '99, we remotely reconfigured the network topology, performed node-to-node ranging, and exercised node-to-node data packet transfer. Seaweb '99 was a successful start in a series of incrementally evolving technology implementations supporting the FRONT scientific obectives.

ForeFRONT-1 and FRONT-1 tested communications in a winter environment with higher ambient noise and upward refracting sound propagation. These conditions caused scattering of sound energy at the sea surface and overall reduced signal-to-noise ratios (SNR). Thus communications range was limited. Communication performance was measured over an 8-day period during which high winds correlated with impaired quality of service as shown in Figure 5.

ForeFRONT-2 tested communications in a spring/summer environment with highly variable conditions. During ForeFRONT-2, communications were achieved to ranges of 10 km. Most measurements involved transmission of 255-byte packets at rates of 300 bits/s. Listening modems at various ranges logged SNR, automatic gain control (AGC), cyclic redundancy checks (CRC), bit-error rates (BER), and decoded data packets. Two sensor nodes and a telesonar testbed transmitted signals according to a time-division-multiple-access (TDMA) schedule.

FRONT-2 focused on networked data delivery and network control. Figures 6 and 7 present the network configuration.

IMPACT / APPLICATIONS

FRONT provides an immediate non-military application for Navy seaweb technology, thereby accelerating its development. FRONT demonstrates the application of seaweb networks for remote sensing of oceanographic phenomena using deployable, autonomous, distributed nodes. The wireless

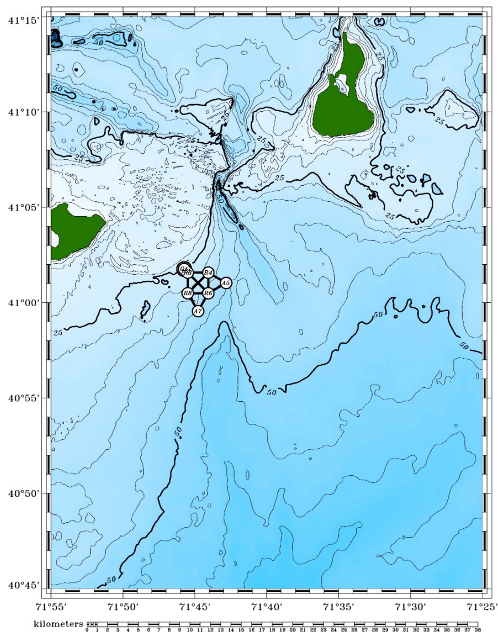

Figure 6. The FRONT-2 network near Montauk Point and Block Island.

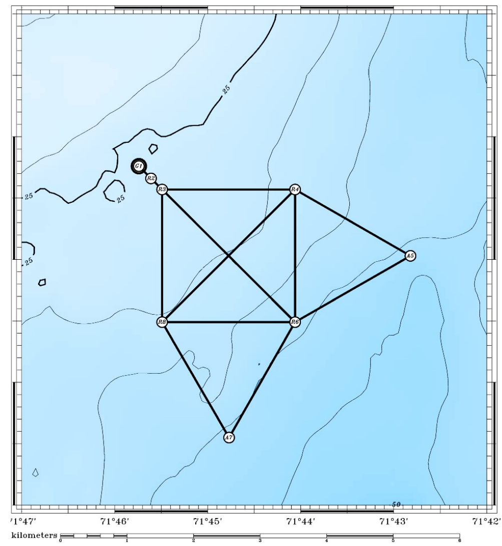

Figure 7. The ADCP sensors are the most easterly and southerly nodes. FRONT-2 exercised various compound routes delivering data packets via five repeater nodes to the northerly gateway node.

command and communications architecture provides the researcher great flexibility for deploying his sensor resources in a given ocean environment.

TRANSITIONS

FRONT furthers the concept of the Seaweb undersea wireless internet for overarching command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR), including network-centric operations in the undersea battlespace. Telesonar technology enables deployable autonomous distributed systems (DADS) and other undersea-warfare applications. Because certain DADS technologies are not yet mature enough to permit realization of the DADS concept, FRONT presents an unclassified application with similar operating environment, node spacing, and data rates. FRONT deployments can include planned outages during which surveillance applications and other undersea applications may be explored using the communications infrastructure. The FRONT installations permit prolonged observation of the relationship between network performance and independently observed environmental influences. A by-product of the FRONT partnership is the availability of time-variant oceanographic data--measured and predicted--for validating and refining numerical telesonar channel models.

RELATED PROJECTS

This is one of several FRONT projects coordinated by U Conn and funded by NOPP.

This project is also performed as a component of the SSC San Diego Seaweb Initiative. Seaweb is a concept for telesonar network infrastructure linking autonomous undersea assets and including gateways to manned command centers submerged, afloat, aloft, and ashore. SSC San Diego has

established the Seaweb Initiative as an internally funded umbrella program advancing telesonar C^4ISR. The Seaweb Initiative coordinates the following telesonar research & development efforts:

- SSC SD ILIR Telesonar Channels Project (6.1)
- ONR 321SS Telesonar Technology Project (6.2)
- ONR 322OM Telesonar Signal Performance Project (6.2)
- ONR 321SI DADS Data Fusion Network Task (6.2)
- ONR 321SS Sublink Task (6.2)
- ONR 321SS Hydra/Kelp Project (6.2)
- ONR 321SS Telesonar Surveillance Applications Project (6.3)
- ONR 321SI DADS Demonstration Project (6.3)
- ONR 36 SBIR topic N93-170 (telesonar modems)
- ONR 36 SBIR topic N97-106 (telesonar networks)
- ONR 36 SBIR topic N99-011 (telesonar directional transducers)

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